FEAMAC Example 4

***Description*:**

This FEAMAC example problem involves the analysis of a composite four-point bend specimen. The specimen geometry is shown in Fig. 17, and the quarter-symmetry finite element mesh, consisting of 2142 C3D8 elements, is shown in Fig. 18. The loading (labeled P in Fig. 17) is applied to elements 639 and 640 (see Fig. 18) as a distributed load using the ABAQUS `*DLOAD` specification. This loading corresponds to a pressure distributed on the top surface of these two elements over a total area of (0.2 mm) × (2 mm) × 2 = 0.8 mm^2. The final multiple of 2 is due to the symmetry of the model. The equivalent force load corresponding to the applied pressure is thus 0.8 mm^2 times the pressure. The bottom surface support boundary condition is modeled as a roller (see Fig. 17). The material is again a SiC/Ti composite with a simple 2×2 GMC repeating unit cell, but this time with a fiber volume fraction of 25%. All elements and integration points again utilize MAC/GMC to provide the material constitutive response. By commenting and un-commenting lines in the ABAQUS and FEAMAC input files, simulations of both a longitudinally reinforced and transversely reinforced composite specimen are performed. An analytical solution for the midspan deflection of the four-point bend specimen is available from elastic beam theory. The midspan deflection, v_{midspan}, is given by,

$$v_{\text{midspan}} = -\frac{Pa}{24EI}\left(3L^2 - 4a^2\right)$$

where P is the applied force loading, E is the modulus along the specimen (x-direction in Fig. 17), I is the moment of inertia, and L and a are defined in Fig. 19.

Required Files:

The following files should be placed in the ABAQUS working directory:

File	Purpose
`feamac_ex4.inp`	ABAQUS input file
`SiC-Ti_25.mac`	MAC/GMC input file describing the SiC/Ti composite material
`feamac.for`	User-defined subroutines for FEAMAC

Note that the `SiC-Ti_25.mac` MAC/GMC input file utilizes material properties in ksi units, while the `feamac_ex4.inp` ABAQUS input file utilizes length units of mm and pressure units of MPa. The `*CONVERT` specification has thus been employed in the MAC/GMC input file with a specified conversion factor of 6.895 MPa/ksi. This will cause the MAC/GMC stress and stiffness components, which are in ksi, to be multiplied by 6.895 MPa/ksi before they are passed to ABAQUS. As such, the ABAQUS-level results will be output in units of MPa, while the MAC/GMC-level results will be output in ksi.

Execution:

This problem can be executed via the following command at the ABAQUS command line:

```
abaqus –j feamac_ex4 –user feamac interactive
```

The `–j` specification indicates the job name (i.e., ABAQUS input file name), while the `–user` specification indicates the file containing the FEAMAC user-defined subroutines. The `interactive` specification provides detailed information on the problem execution during the execution and is optional.

Output:

The output for this problem is written to the ABAQUS output database file `feamac_ex4.odb` for post-processing in ABAQUS/CAE, ABAQUS/Viewer, or other appropriate finite element post-processing software. No MAC/GMC xy plot data output is written in this problem. A MAC/GMC output file, `SiC-Ti_25.out`, is also written. This file contains the composite material effective properties needed for use in the analytical midspan deflection equation given above.

Results:

Figure 20 compares the midspan deflection for the four-point bend specimen as a function of the increasing applied load predicted by FEAMAC with the analytical elastic beam theory solution. The FEAMAC prediction is virtually identical to the beam theory equation for both the longitudinal and transverse fiber orientations until the onset of matrix yielding. Then, due to the increased rate of deformation associated with the inelasticity, the FEAMAC curves diverge from the linear beam theory curves. Figures 21 – 24 show the von Mises stress and equivalent plastic strain fields predicted by FEAMAC for the longitudinal and transverse specimens upon completion of the applied load. Note that the total applied load is different for the longitudinal and transverse specimens.

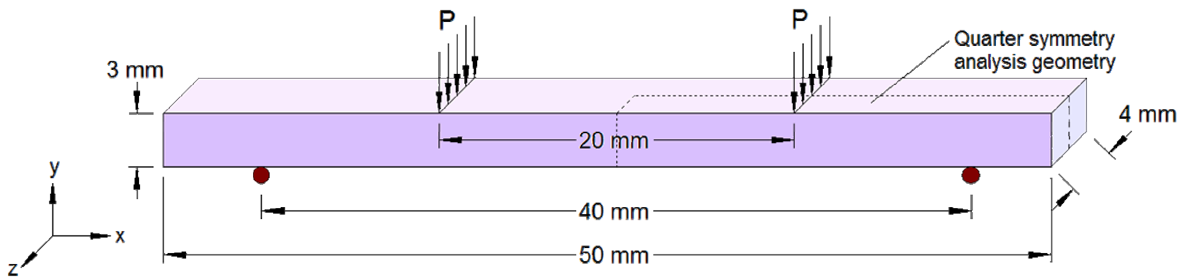

Fig. 17. Four-point bend specimen geometry, dimensions, and loading.

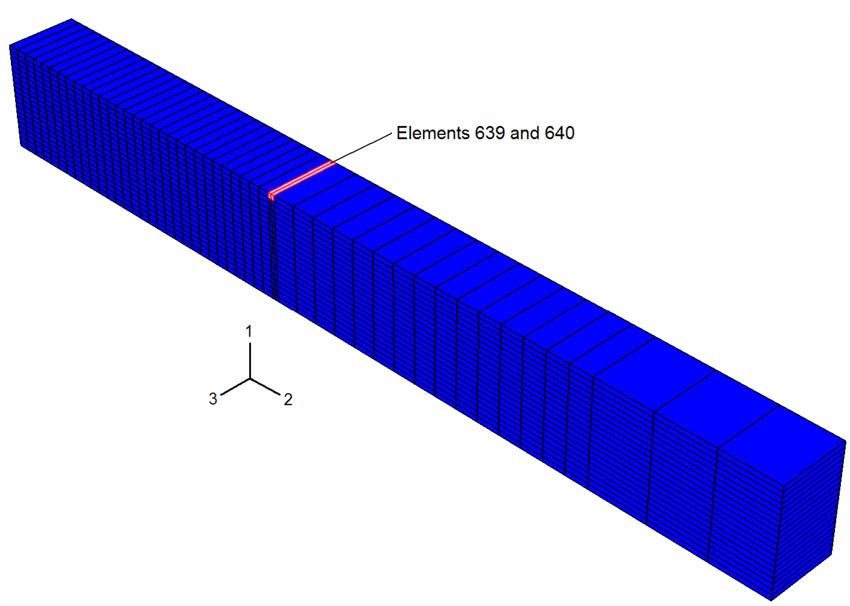

Fig. 18. Four-point bend specimen quarter-symmetry ABAQUS mesh consisting of 2142 C3D8 elements.

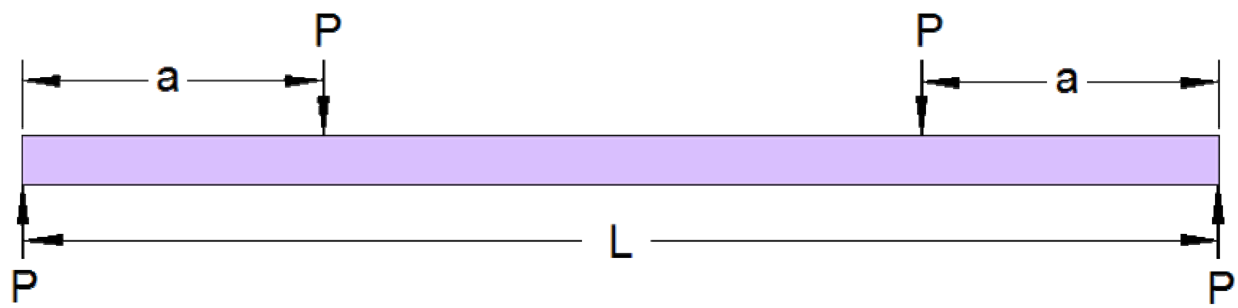

Fig. 19. Four-point bend analytical elastic beam theory solution geometry.

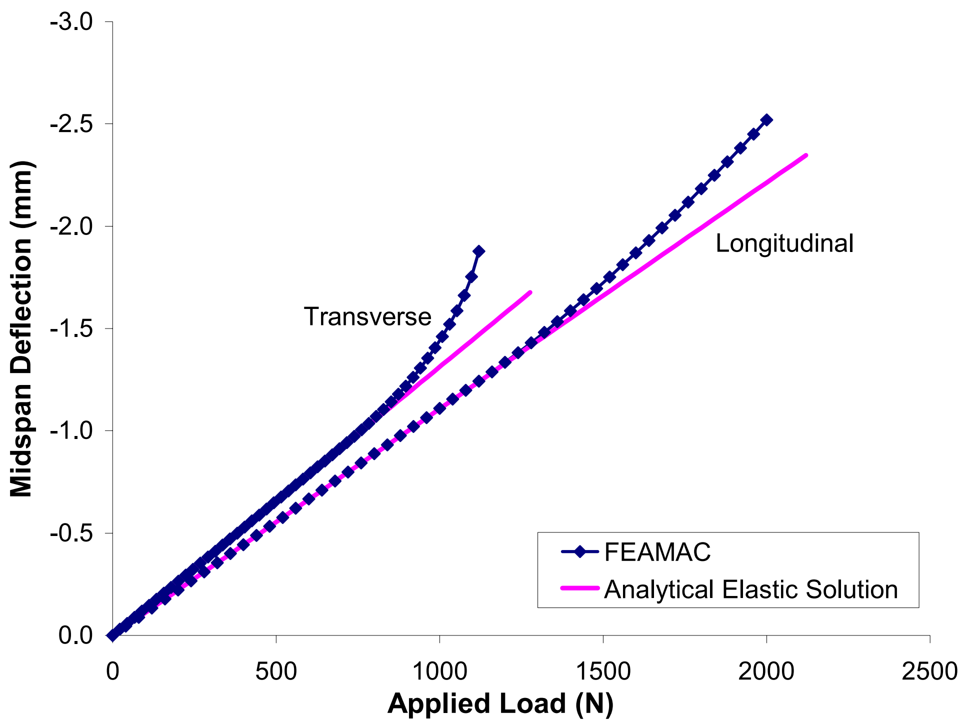

Fig. 20. Comparison of the four-point bend specimen midspan deflection predicted by viscoplastic FEAMAC and the analytical elastic beam theory solution for a 25% SiC/Ti composite material.

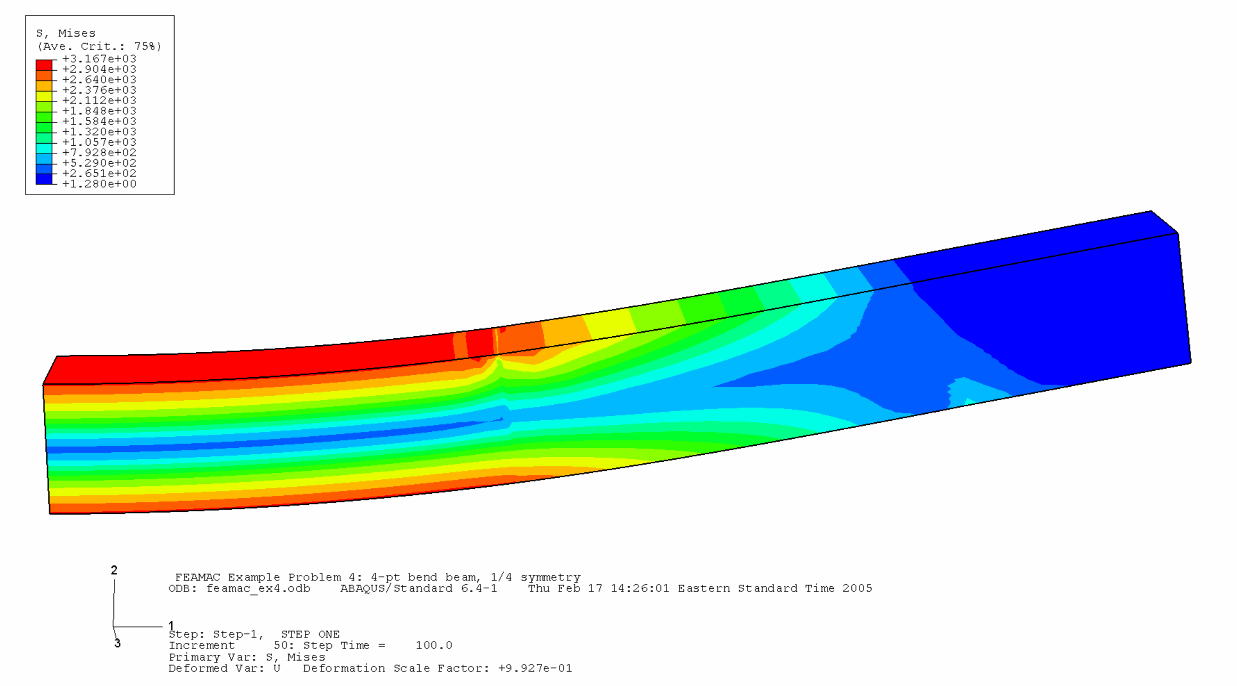

Fig. 21. von Mises stress field (MPa) in the longitudinal 25% SiC/Ti four-point bend specimen predicted by FEAMAC. Applied force = 2000 N.

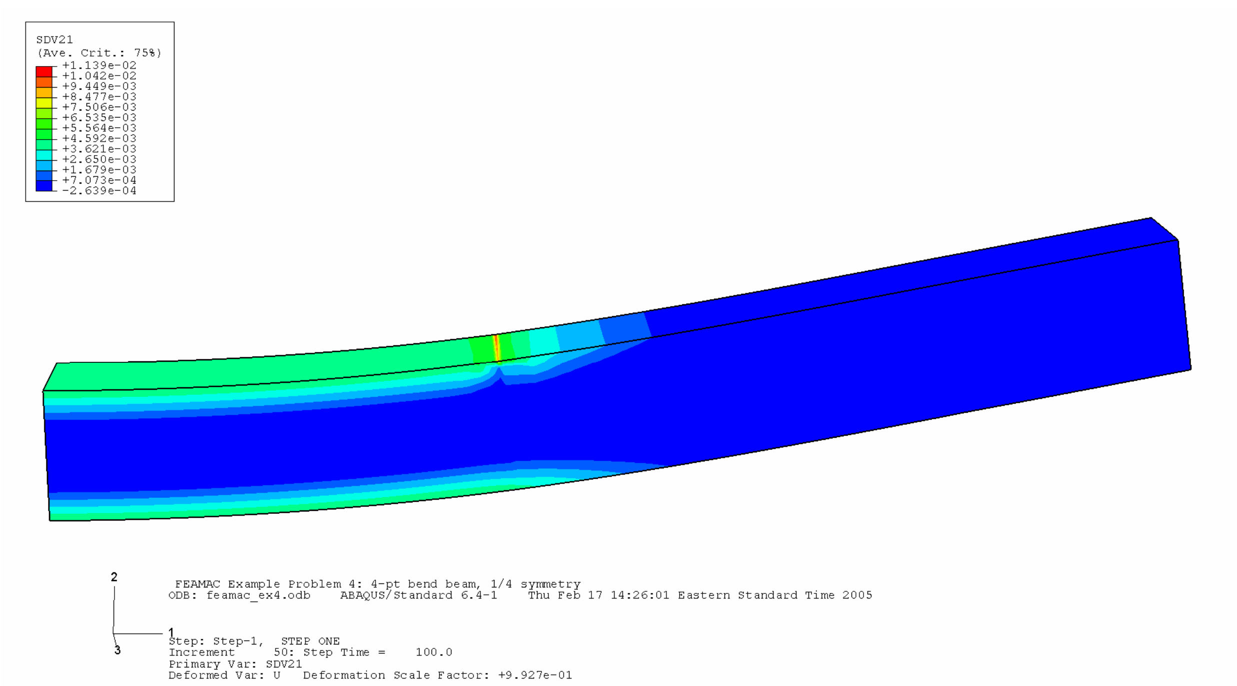

Fig. 22. Equivalent plastic strain field in the longitudinal 25% SiC/Ti four-point bend specimen predicted by FEAMAC. Applied force = 2000 N.

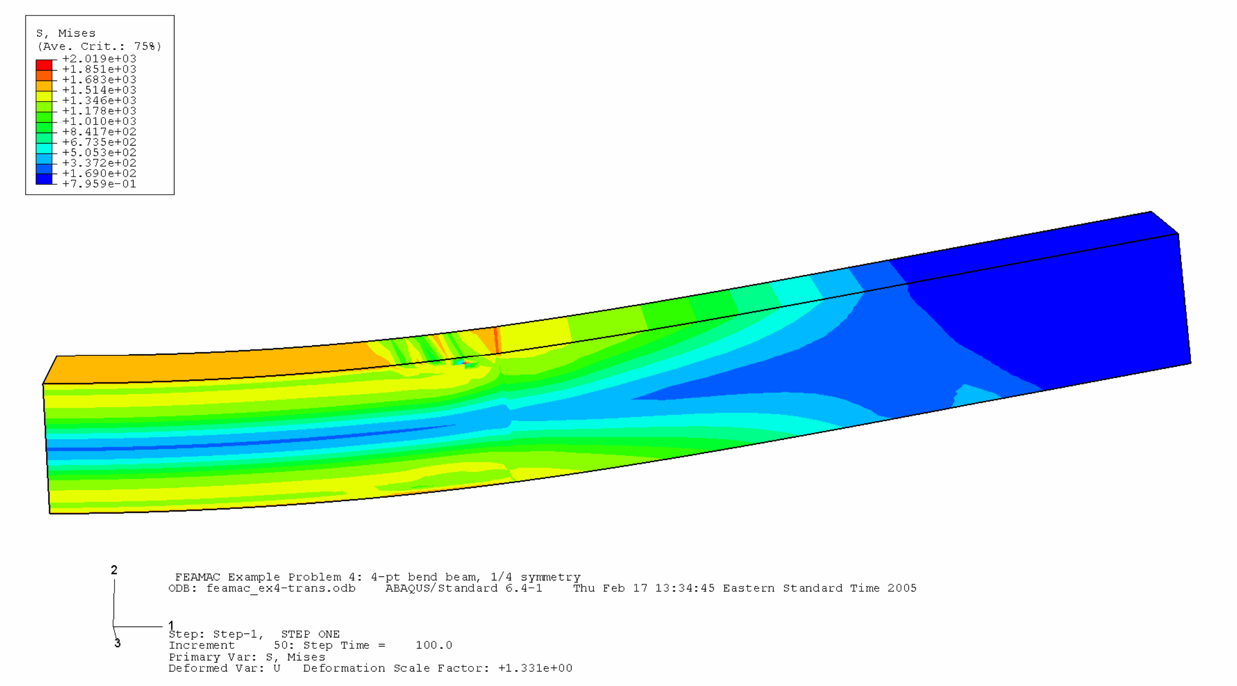

Fig. 23. von Mises stress field (MPa) in the transverse 25% SiC/Ti four-point bend specimen predicted by FEAMAC. Applied force = 1120 N.

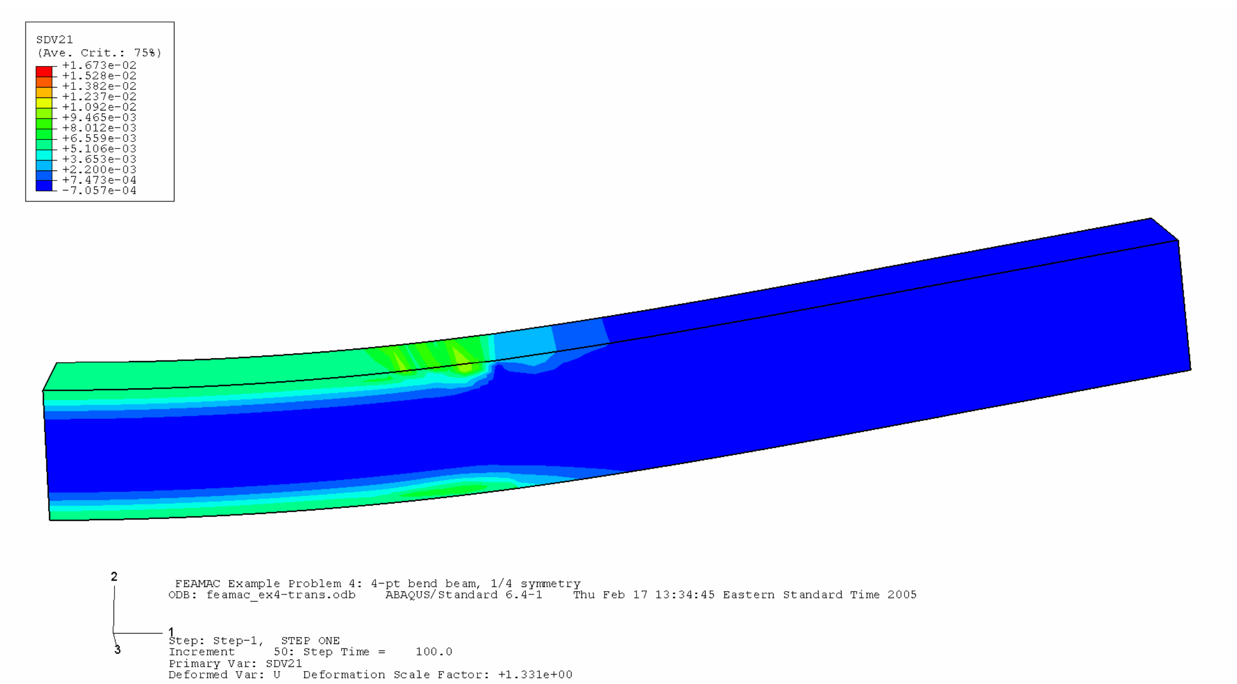

Fig. 24. Equivalent plastic strain field (MPa) in the transverse 25% SiC/Ti four-point bend specimen predicted by FEAMAC. Applied force = 1120 N.